



## Interactive Geometry Remeshing

Pierre Alliez  
Mark Meyer  
Mathieu Desbrun

INRIA  
Caltech  
USC

## Digital Geometry Processing

### Foundations for mesh processing

- Parameterization
- Resampling and Remeshing
- Processing



## Talk Layout

- Motivation & Previous Work
- Interactive Geometry Processing
  - Geometry Analysis
  - Resampling Design
  - Remeshing
- Results
- Conclusions & Future Work

## Previous Work

Two very different fields,  
two very different goals:

- **Finite Element community:**  
High-quality meshes for simulation:  
remeshing with good aspect ratio
- **Computer Graphics community:**  
3D meshes for the masses:  
levels of detail for fast display



## Finite Elements

### Use of parametric space

'96	De Cougny & Shepard	Geometry matching
'96	Bossen & Heckbert	2D anisotropic
'97	Borouchaki <i>et al.</i>	Delaunay / metrics
'98	Tristano <i>et al.</i>	Advancing front

### ... or of an explicit mesh

'97	Véron	Adaptation
'00	Frey	Optimization
'00	Rassineux <i>et al.</i>	Moving least squares

## Computer Graphics

101 ways to alter sampling and geometry:

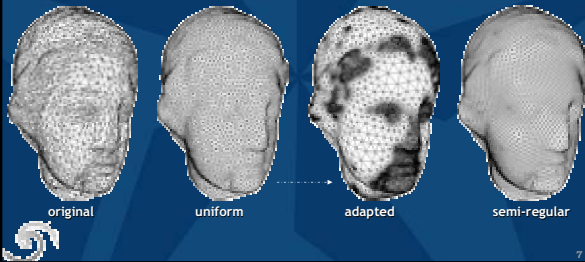
- **Decimation** [Hoppe '96, Garland & Heckbert '98, Lindstrom & Turk '98, ...]
- **Refinement** [Turk '92, Boissonnat & Cazals '01]
- **Subdivision surfaces** [Guskov *et al.* '98, Kobbelt '98, Maillot & Stam '01...]
- **Spectral approach** [Pauly & Gross '01]
- **Feature remeshing** [Kobbelt *et al.* '01]

*Often hard/impossible to control  
the design of the output mesh*

## What Remeshing Needs (I)

- **Generality**

From uniform to curvature-adapted meshes...  
in a unified pipeline



7

## What Remeshing Needs (II)

- **Flexibility**

- Control over the design of the remeshing
  - Resampling (curvature-based, user-defined,...)
  - Connectivity (valence dispersion, aspect ratio,...)
- Feature preservation

- **Efficiency**

- Routine operation, as fast as possible
- Realtime preview for easier design
- Slower only if high accuracy is required



8

## What We Propose

### Interactive Geometry Remeshing

Three main ideas:

- **Work in parameter space:**  
2D space, much easier/faster!
- **Use a density map to design the sampling:**  
Density map can be computed and/or painted
- **Avoid long optimizations as much as we can:**  
Error diffusion for near-optimal vertex placement



9

## Our Method At a Glance

### Remeshing Pipeline:

- **Geometry Analysis** - input-dependent
  - Parameterization** (remove embedding)
  - Geometry Maps** (2D images to substitute for 3D)
- **Remeshing Design** - realtime
  - Flexible Design** (use conventional DSP tools)
  - Realtime Resampling** (use error diffusion)
- **Mesh Generation** - output-dependent
  - Triangulation and Reprojection** (2D back to 3D)
  - Final Optimization** (only if needed!)



10

## Our Method At a Glance

### Remeshing Pipeline:

- **Geometry Analysis** - input-dependent
  - Parameterization** (remove embedding)
  - Geometry Maps** (2D images to substitute for 3D)
- **Remeshing Design** - realtime
  - Flexible Design** (use conventional DSP tools)
  - Realtime Resampling** (use error diffusion)
- **Mesh Generation** - output-dependent
  - Triangulation and Reprojection** (2D back to 3D)
  - Final Optimization** (only if needed!)



11

## Geometry Analysis (I)

- **Creating an Atlas of Charts**

Use, for instance: [Grimm & Hughes '95, Garland *et al.* '01, Pauly & Gross '01, Lévy *et al.* '02]

- **Removing the Embedding**

Parameterize the charts to work in 2D

- **Conformal recommended!**  
[Pinkall & Polthier '93, Eck *et al.* '95, Haker *et al.* '00, Lévy *et al.* '02, Desbrun *et al.* '02]



12

## Geometry Analysis (II)

- **Precomputing Geometry Maps**

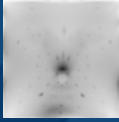
- Substitute **2D maps** for the geometry:

Area stretch, mean and gaussian curvatures,  
 $x, y, z$ , normal map, etc...

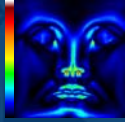
- Use **OpenGL** to draw the maps faster ( $\times 10^3$ )



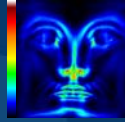
Parametric domain



Area stretching



Mean curvature



Gaussian curvature



Discrete Differential-Geometry Operators for  
Triangulated 2-Manifolds, [Meyer et al. 02]